Signal Integrity eSeminar Series Q&A: Analyzing Digital Jitter and its Components

The following Questions and Answers were created from the live eSeminar broadcast of January 22, 2004. You can view the archived eSeminar by going to **www.agilent.com/find/sigint** and selecting it from the list of Signal Integrity Series eSeminars.

Q: How does jitter effect the end user?
A: The bottom line for a communication system is are the bits getting to the other end without error? That measurement is achieved with bit error ratio. We're trying to hit one in a trillion type levels of performance. This jitter measurement technique is how can you really characterize jitter down to those fine levels. The bottom line is jitter, if it becomes large enough, causes a receiver to make mistakes, degrades your bit error ratio, and your system performance is probably not going to cut it unless you're able to control those jitter levels to achieve your required BERs.

Q: Is this functionality available on an 86100A or 86100B?
A: No. This functionality is only available on the 86100C. That really goes back to the point about the new triggering hardware. There is fundamentally different hardware in the 86100C as compared to the 86100A and B, so it's only available on the C. But all of the modules that you have for an 86100A or B will work in the C.

Q: How many samples or waveforms do you have to measure before you have a statistically accurate result for measuring jitter? PCI Express says 10 Kb bits.
A: The DCA-J collects data in a fundamentally different fashion than a real-time oscilloscope. Some standards measurements are based on a real-time oscilloscope, one that acquires a data set in a real-time fashion. For an equivalent time sampling scope to make an accurate measurement, it's not so much how many samples we acquire but literally have we been able to go through the entire pattern. Really the prerequisite for us making an accurate measurement is that you have to allow us enough time to get through the pattern. It could be as short as just a few seconds, and for very long patterns it could take as much as a minute. So, where PCI-Express calls out 10k bits, it isn't an "apples-to-apples" comparison. The key thing for the DCA-J is to make at least one complete pass through the pattern for DDJ measurements in order for the statistics to be complete. The number of samples that are taken to achieve a complete pass will depend on the length of the pattern.

Q: How long does it take to measure all the jitter components?
A: It does depend on the pattern length. For very short patterns such as a PRBS-7, it's just a few seconds. In the case of a PRBS-15 pattern, it's on the order of about 45 seconds to a minute, depending on the amount and makeup of the jitter, but typically on the order of a minute for a PRBS-15.

Q: Is all the uncorrelated data collected from the same edge?
A: We have to collect correlated and uncorrelated data. Technically the uncorrelated results should not really depend on which edge that you acquired from. In theory you should be able to collect all that data from a single edge. It turns out that we don't do that, that we'll collect quite a bit from an edge. As we work our way along, we'll actually collect data from several edges and combine the results. Even though theory says we shouldn't have to, we go ahead and do it anyway.

Q: What is the price of a 86100C DCA-J?

A: That depends on the configuration. For the functionality that we've talked about here today, that would be an 86100C mainframe with option 001 (enhanced trigger) and option 100 (jitter analysis software). In the U.S. the price is around $31,000.

Q: Are you able to do bathtub curves?

A: Yes. The bathtub curve is essentially when you've put all the jitter elements together and you want to be able to predict down to these low bit error ratios, that it is based on a bathtub curve approach where we actually are able to project down. In a case we've shown several times, 1×10^{-12}. A bathtub curve is something that we're in the process of rolling out and will be available. On March 1, 2004 we will be introducing a new software package – option 101 Advanced Waveform Analysis on the DCA-J. This will provide a bathtub curve display in Jitter Mode.

Q: Have you any correlation data using your BER instrument to measure the same waveforms that you showed?

A: We don't have specific BER measurements on those specific waveforms, but we have done a lot of correlation experiments with bit error ratio testers in our labs and have a very good correlation. We've actually done a lot of work in that area and we'll be publishing some of that data over the next few months. One more point to clarify on the bathtub question. We have a new software option (#101) that will be introduced March 1, 2004 that will actually give a bathtub display.

Q: How does measuring random jitter in the low kHz region effect the results given that the RJ is typically higher there than the Nyquist down to the standards corner frequency?

A: The amount of the low frequency RJ that is measured will depend on the clock source that is used as the trigger signal. If clock data recovery (CDR) is used, the jitter within the loop bandwidth of the CDR (below the corner frequency) will not be present in the measurement. On the other hand, if a direct clock is used, such as a synthesizer that is phase locked to the data signal, all frequency content of the jitter will contribute to the measurement. Both measurement scenarios are helpful in understanding the jitter that is present.

Q: What happens when the RJ PJ histogram is not a Dual Dirac?

A: The RJ, PJ histogram need not have a pure dual Dirac-delta shape in order to be modeled by one. The key intent of the model is to determine the impact of the periodic jitter at very low bit error ratio (BER) levels. In most applications the PJ will typically have a complex distribution that isn't completely described by any given, well known model. However, the dual Dirac-delta model is a great tool to assess and describe the impact of the PJ at low probabilities.

Q: How many edge transfer function models do you have?

A: There can be up to as many single-edge models as there are edges in the pattern, and there are 16 composite-edge models. Two types of edge models are used: single-edge models and composite-edge models. A single-edge model is constructed by taking samples across the entire span of one edge. A composite-edge model is very similar, except the samples used to construct the model are taken from multiple edges. A single-edge model is used to describe the amplitude-to-jitter characteristics of a specific edge of a pattern. Composite-edge models are used to describe the amplitude-to-jitter characteristics of a class of edges. A class is defined by two factors – rising versus falling and the four preceding bits. For example, '00001' is one class of rising edge, and '00101' is another. Similarly, '11110' is one class of falling edge, and '11010' is another. Consequently, 16 edge classes are defined – 8 rising and 8 falling. A white paper, "Jitter Separation - 50 Mb/s to Over 40 Gb/s Using the Agilent 86100C Infiniium DCA-J" is available on our web page at **www.agilent.com/find/dca** that describes the edge models in more detail.

Q: Why doesn't your PJ, DCD, and ISI add up to your total DJ in your examples?

A: While PJ, DDJ, ISI, and DCD are all forms of deterministic jitter, DJ is not a simple arithmetic sum of these constituent components. Rather, the DJ distribution is a result of the convolution of the constituent distributions. The DJ value that is reported is intended to describe the combined impact of all of the constituent components at low bit error ratio (BER).

Q: You mention a new trigger hardware approach, can you explain me more detail of how it works?

A: A pattern trigger can be derived from a system clock signal. One must know the length of the pattern and the ratio of the data rate to the system clock rate. For example, in the case of the full rate clock, if the pattern length is N, a strobe signal should be generated every time that N clock cycles have been counted. A white paper, “Jitter Separation - 50 Mb/s to Over 40 Gb/s Using the Agilent 86100C Infiniium DCA-J” is available on our web page at **www.agilent.com/find/dca** that describes the operation in more detail.

Q: How do you separate out the different types of jitter?
A: Slides 19 through 31 of the NetSeminar presentation describe the process used by the DCA-J to separate jitter. A white paper, “Jitter Separation - 50 Mb/s to Over 40 Gb/s Using the Agilent 86100C Infiniium DCA-J”, is available on our web page at **www.agilent.com/find/dca** that describes the process in more detail.

Q: So you are using a worst-case bit pattern? Where does that come from?
A: The data shown in this presentation was measured using a pseudo random bit sequence (PRBS) of length 2^{10}-1 bits. The signal was generated with an Agilent 81134A pulse pattern generator. The DCA-J will work with any repeating pattern up to a length of 32768 bits (longer in a future software release). The bit pattern is typically determined by the end-user based on their application. In end-user applications the signal typically is provided by an instrument such as a pattern generator or bit error ratio tester (BERT). Many emerging devices under test (DUTs) have the capability of generating test patterns internally.

Q: Is Spread Spectrum Clocking supported?
A: Spread spectrum clocking can be a challenge. I am assuming that your application uses something similar to that called out for PCI-Express (up to 33 kHz). If you are trying to characterize the jitter performance of your device or system assuming that your receiver’s clock recovery will track out the impact of the spread spectrum clock, then the DCA-J measures that by using a clock with the spread spectrum content as the trigger signal. This is typically the reference clock. If you want to observe the spread spectrum clock content on the data as jitter, you would use a clean (not spread) clock that is synchronous with the data as your trigger source.

Q: At what rate can you predict the error ratio down to?
A: Regarding how far down in probability we can project the total jitter value, there really is no hard limit. At some point, the late edges from the left crossing point begin meeting the early edges from the right crossing point, which alters how we look at the effect on BER, but strictly looking at jitter you can project out indefinitely. The feature is under construction, and we will put some limit on it, but it's still to be determined.

Q: Does the distribution of the PJ influence the validity of the Dual Dirac approach?
A: The PJ distribution influences how the PJ value we back out of the model should be interpreted. The dual Dirac model gives you the periodic jitter in terms of how the random jitter is 'split' and effectively locates the position of the low probability extremes of the RJ/PJ histogram. The width of the split is what we provide as the PJ 'delta-delta' value. If one were to take this value and blindly interpret this to be the amplitude of the periodic jitter, they could possibly be misled. Consider that for a square wave or sine wave jitter signal of equal amplitudes, the 10^{-12} probability jitter position will be at different time positions (assuming a constant RJ value). In other words, the square wave yields a worse TJ value. To deal with this, we also report an rms value for the PJ. This yields the effective periodic jitter, independent of the PJ distribution.

Q: Can I get a copy of the presentation?
A: Yes, go to eSeminar archive. When the window opens there will be a row of button at the bottom of the window, such as “Transcript”, “Slide Download”, “Events”, and “Resources”. If you click on Resources, the Agilent Resource page will be displayed, where you can get a copy of the presentation plus find many valuable links for more information on the subject. There is also a Digital discussion forum (**www.agilent.com/find/forums**) if you would like to pose/review other questions.

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